The Nature of Faint Blue Stars in the PHL and Ton Catalogues based on Digital Sky Surveys

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Abstract We determined accurate positions for 3000 of the "faint blue stars" in the PHL (Palomar-Haro-Luyten) and Ton/Ton S catalogues. These were published from 1957 to 1962, and, aimed at finding new white dwarfs, provide approximate positions for ∼10,750 blue stellar objects. Some of these "stars" had become known as quasars, a type of objects unheard-of before 1963. We derived subarcsec positions from a comparison of published finding charts with images from the first-epoch Digitized Sky Survey. Numerous objects are now well known, but unfortunately neither their PHL or Ton numbers, nor their discoverers, are recognized in current databases. A comparison with modern radio, IR, UV and X-ray surveys leads us to suggest that the fraction of extragalactic objects in the PHL and Ton catalogues is at least 15 %. However, because we failed to locate the original PHL plates or finding charts, it may be impossible to correctly identify the remaining 7726 PHL objects.

1 Introduction and Motivation for this Work

In 1947 Humason & Zwicky [10] searched for faint blue stars using 4-filter photography, with the aim to find new white dwarfs (WDs). Motivated by this, Luyten [14] surveyed the north Galactic cap for faint blue stars with red and blue plates. This, in turn, prompted G. Haro to search systematically for blue stars using three

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exposures on the same plate. This resulted in (a) the "Ton" and "Ton S" lists of 2008 faint blue objects in the north [12, 4] and south [3] Galactic caps from Tonantzintla Schmidt telescope plates, and (b) a list of 8746 "PHL" objects from 49 Palomar 48-inch Schmidt plates [8]. One year later, the first radio-loud quasar was reported [18], and within another two years, radio-quiet quasars were found to be $\sim$10 times more common than radio-loud ones [17]. Some of the PHL or Ton objects became very famous, like, e.g., the high-redshift QSOs PHL 2871 (3C 9) or PHL 957. In fact, 25 PHL objects have over 200 references in Simbad [19] ($\sim$50 % are Seyfert galaxies or QSOs, and the remainder are Galactic stars).

While Simbad contains all 8746 PHL objects, 94.6 % of these are listed with their poor original position ($\pm \sim 1.5'$), and only 490 (5.6%) appear with more precise positions (150 QSOs or AGN, 160 WDs, and 180 stars of other types). On the other hand, NED [15] recognizes only 302 (3.5 %) of all PHL objects (113 QSOs, 21 galaxies, 144 stars, 8 WDs and 16 of unknown type). Unfortunately, neither NED nor Simbad quote the detection paper [8] for *any* of the PHL/Ton objects they contain. This motivated us to try to determine precise positions for those PHL and Ton objects with published finding charts (FCs) in order to: (a) assess how many are already known (with other names) in astronomical databases, (b) estimate the fraction of extragalactic objects among them, and (c) give credit to the original discoverers.

2 Procedure and Results

While the Ton and Ton S catalogues [12, 4, 3] included FCs for all 2008 objects, only for 1020 (12 %) of all PHL objects FCs were published [9, 5, 6, 7]. To identify the correct PHL or Ton object, we displayed the published FCs side-by-side to a similar-sized ($16' \times 16'$) image of the Digitized Sky Survey (DSS) centered on the published position, and then retrieved the position of the marked object to $< 1''$ precision. We chose the blue, first-epoch "DSS1", for being most similar to the published FCs in both color and epoch, to avoid displacements for high proper motion objects.

We were able to identify all 1020 PHL objects, but, owing to some very poor FCs, only $\sim$97 % of the Ton/TonS objects; a few objects were found with the help of astrometry.net [13]. The mean positional offsets for the PHL and Ton/Ton S objects ("published minus DSS") are $21''$ and $7''$ in R.A., and $4''$ and $-11''$ in Decl., with a dispersion in position of $\sim 1'$ for PHL and $\sim 2'$ for Ton/Ton S.

During our work we found several curiosities, like *very large positional offsets*, often due to typos which can be resolved using [13]; *sign errors*: e.g., the Decl. sign for PHL 1 should be negative, since only with this choice there is a blue object near to its published position; *large proper motions* of $\geq 3''$ between the epochs of DSS1 ($\sim$1950) and SDSS ($\sim$2000; [1]) implying proper motions in excess of 60 mas yr^{-1} for several objects; *variability*: a few objects appear on some plates, but not on others, e.g., PHL 6287 is present on DSS1 images, but absent in DSS2 and SDSS. We found some of the cross-identifications with PHL objects proposed by [2] to be false, as can be seen on FCs in [9, 5, 6, 7], which were published *after* [2].

3 Conclusions

For the first time since their publication, we derived accurate positions for all 3000 PHL/Ton objects with available finding charts (FCs). We found erroneous identifications for PHL objects in the literature, caused by the lack of an available FC. Thus, the latter are crucial for an unambiguous identification. Many PHL/Ton objects have become well-known objects, but for none of them the discovery papers are cited in NED or Simbad. Curiously, the best-known PHL objects are *not* those with published FCs which suggests that their positions had either been found from the approximate original ones, or that FCs had been circulated privately by [8]. No traces could be found of the 49 PHL plates, neither at INAOE (Tonantzintla, Mexico, where Haro and Chavira worked), nor at Univ. of Minnesota (where Luyten worked), nor of the corresponding FCs for the remaining 7726 (88 % of all) PHL objects This makes the correct identification of these objects virtually impossible, except perhaps for the $\sim$1400 "very blue" ones in table 2 of [8].

Extragalactic objects may be distinguished from Galactic stars using color indices from IR to UV wavelengths (cf. [11, 16]), or from proper motions (comparing DSS with SDSS positions), or via a detection in radio surveys. Our preliminary cross-correlation with object catalogues in these wavelength ranges leads us to estimate that at least 15 % of the PHL and Ton objects are likely to be extragalactic.

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